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Summers

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(54) **HEAT SHIELD ASSEMBLY FOR USE WITH AN AIRCRAFT ENGINE**

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***B64D 33/04*** (2006.01)
***F02C 7/24*** (2006.01)

(52) **U.S. Cl.**

CPC ................ ***F02C 7/20*** (2013.01); ***B64D 27/18*** (2013.01); ***B64D 29/02*** (2013.01); ***B64D 33/04*** (2013.01); ***F02C 7/24*** (2013.01); *F05D 2220/323* (2013.01); *F05D 2260/231* (2013.01)

(58) **Field of Classification Search**

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See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,712,750 A * 12/1987 Ridgwell .................. F02K 1/52 244/54
5,524,846 A * 6/1996 Shine ...................... F02K 1/805 60/796
6,829,883 B2 * 12/2004 Sathianathan ............ F16B 5/02 403/150
7,121,758 B2 * 10/2006 McMillan ............. F01D 21/045 403/336

(Continued)

FOREIGN PATENT DOCUMENTS

EP 3275788 A1 1/2018
WO 2014135948 A3 9/2014

OTHER PUBLICATIONS

Extended European Search Report issued in European Application No. 22180057.6, dated Dec. 5, 2022. pp. 1-7.

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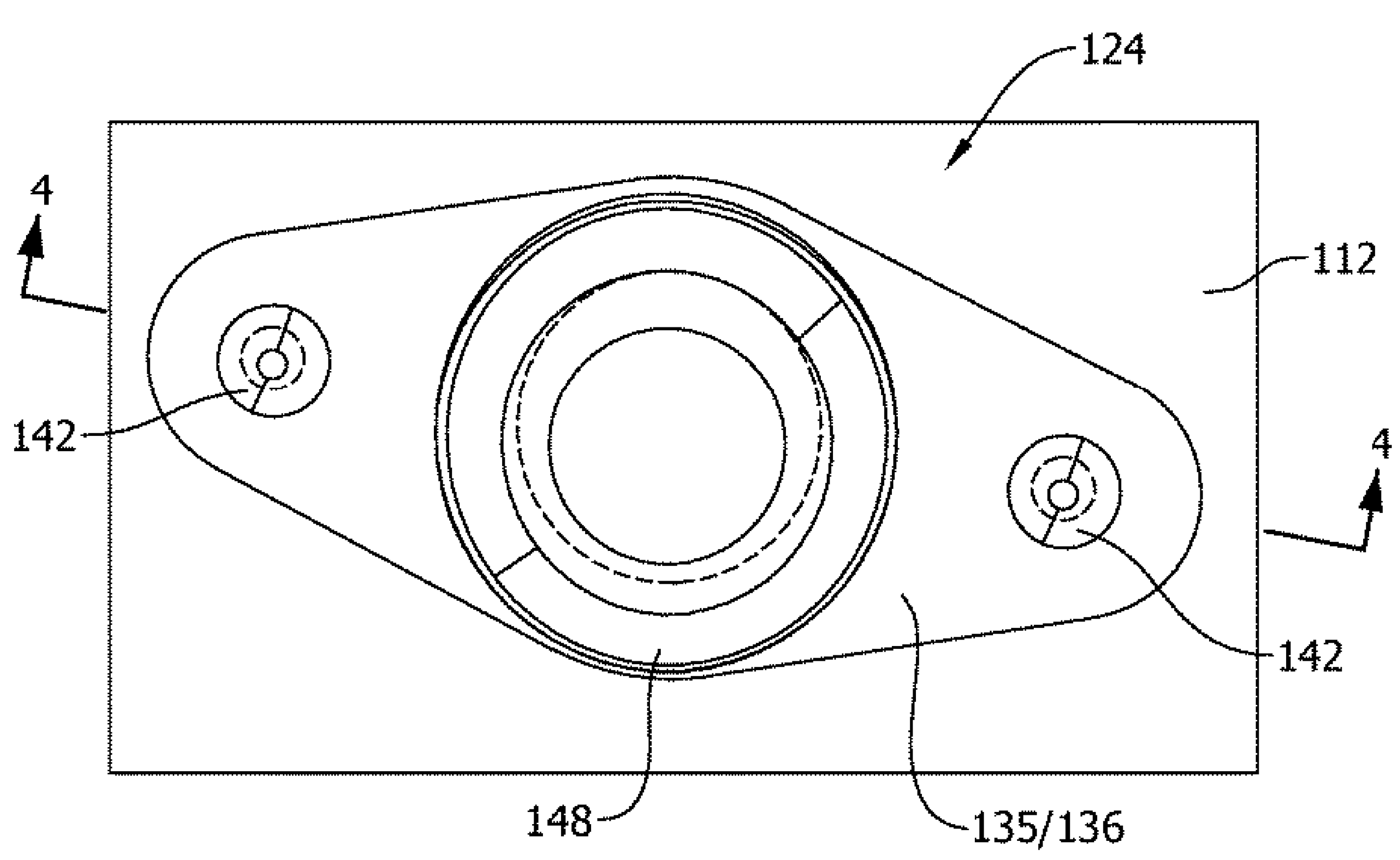
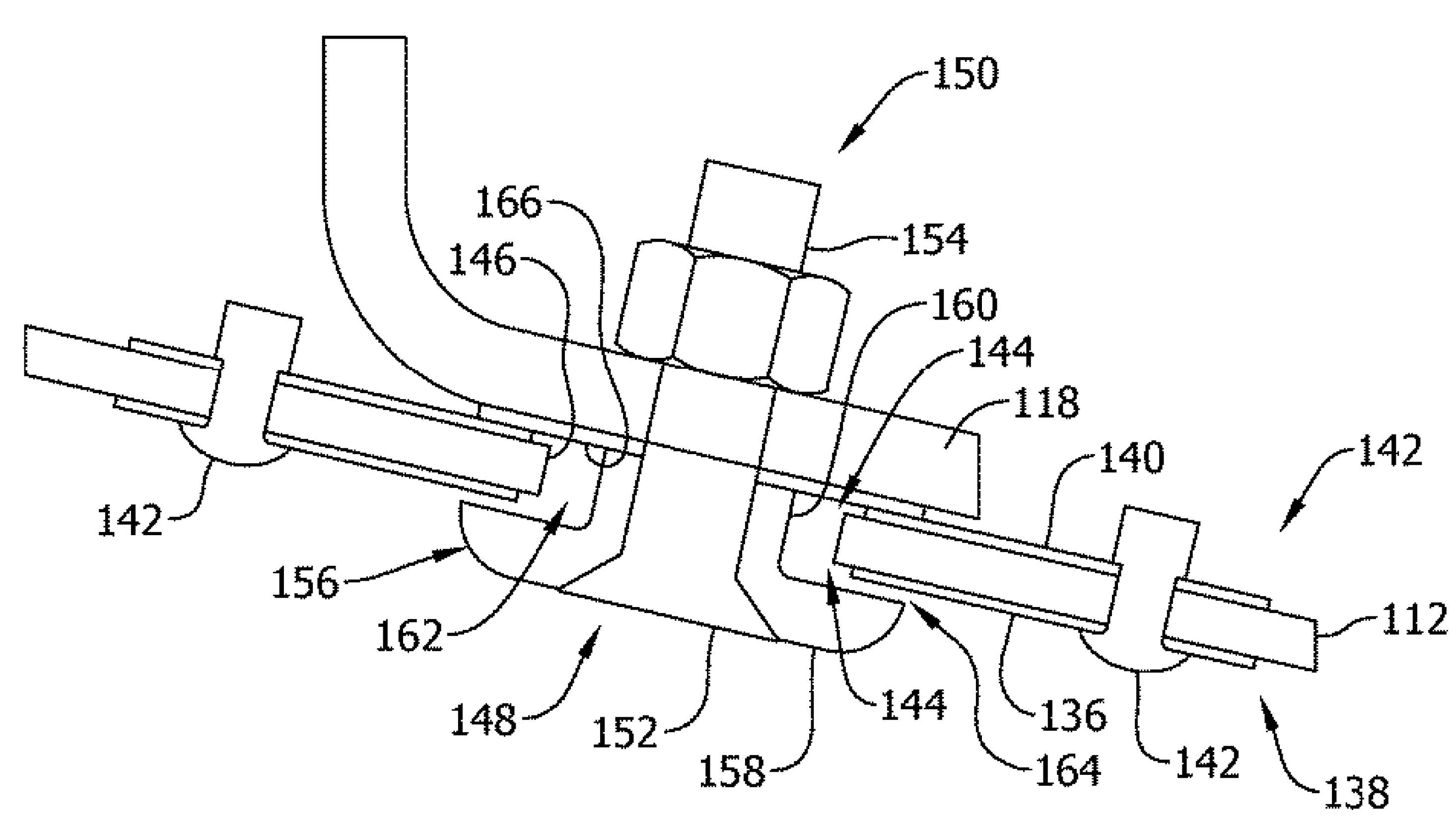
(57) **ABSTRACT**

A heat shield assembly for use with an aircraft engine. The heat shield assembly includes a structural member, a heat shield panel adapted for exposure to aircraft engine exhaust, an index joint coupling the heat shield panel to the structural member in a fixed positional location, and a plurality of slip joints coupling the heat shield panel to the structural member. Each slip joint includes at least one wear buffer coupled to the heat shield panel, and a slip fastener insertable through a slip joint hole in the heat shield panel with a clearance fit. A gap defined by the clearance fit is sized to provide a tolerance for expansion and contraction of the heat shield panel relative to the fixed positional location, and the at least one wear buffer is engageable by the slip fastener during expansion and contraction of the heat shield panel.

**20 Claims, 4 Drawing Sheets**



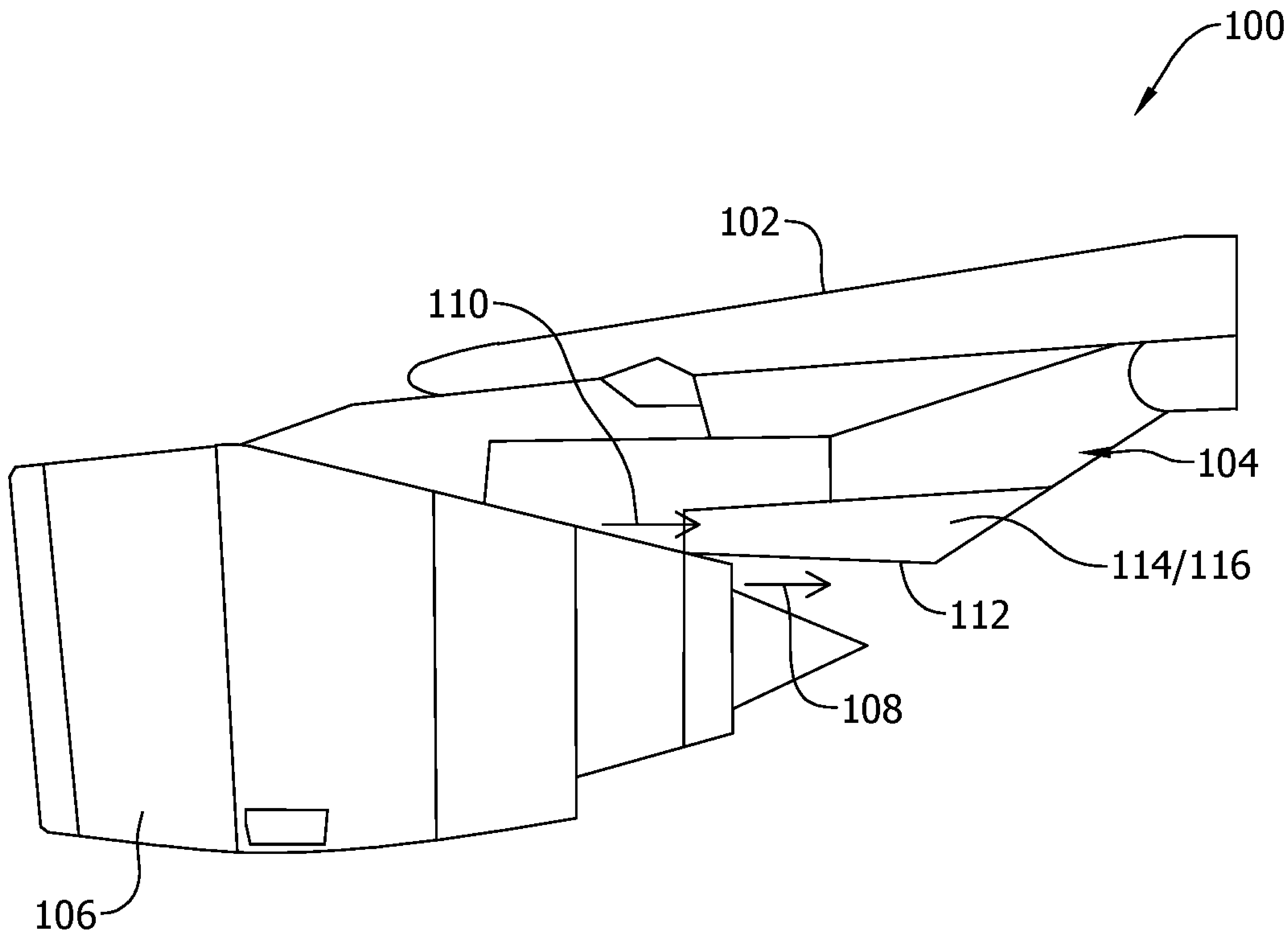



(56) **References Cited**

U.S. PATENT DOCUMENTS

| | | | | |
|---|---|---|---|---|
| 7,581,301 | B2 * | 9/2009 | Arbona | F16B 5/0241 29/525.02 |
| 8,118,252 | B2 * | 2/2012 | Dumont | B64D 33/04 248/556 |
| 8,662,440 | B2 * | 3/2014 | Journade | A61P 29/00 248/556 |
| 8,844,862 | B2 * | 9/2014 | Journade | B64D 29/02 244/54 |
| 9,688,412 | B2 * | 6/2017 | Peyruseigt | B64D 27/26 |
| 10,260,540 | B2 * | 4/2019 | Connelly | F16B 5/0088 |
| 10,385,730 | B2 * | 8/2019 | Acius | F01D 25/28 |
| 11,111,881 | B2 * | 9/2021 | Goudard | F02K 1/76 |
| 11,427,298 | B2 * | 8/2022 | Cromer | B64C 1/38 |
| 2003/0201366 | A1 * | 10/2003 | Connelly | B64D 29/02 244/121 |
| 2008/0178465 | A1 | 7/2008 | Schiavo et al. | |
| 2009/0095443 | A1 * | 4/2009 | Connelly | B64D 29/02 428/157 |
| 2009/0200418 | A1 * | 8/2009 | Beaufort | B64D 27/26 244/54 |
| 2009/0212184 | A1 * | 8/2009 | Bourgeois | F16M 11/2064 248/295.11 |
| 2010/0051743 | A1 * | 3/2010 | Dumont | B64D 29/02 244/54 |
| 2011/0155847 | A1 * | 6/2011 | Journade | A61P 25/28 244/54 |
| 2013/0105622 | A1 * | 5/2013 | Journade | B64C 7/02 244/54 |
| 2018/0016019 | A1 | 1/2018 | Ramlaoui | |
| 2018/0057140 | A1 | 3/2018 | Connelly et al. | |
| 2021/0078693 | A1 | 3/2021 | Cromer et al. | |
| 2022/0128005 | A1 * | 4/2022 | Smith | F01D 1/026 |
| 2022/0221484 | A1 * | 7/2022 | Fewless | G01F 1/42 |

* cited by examiner


100
102
110
104
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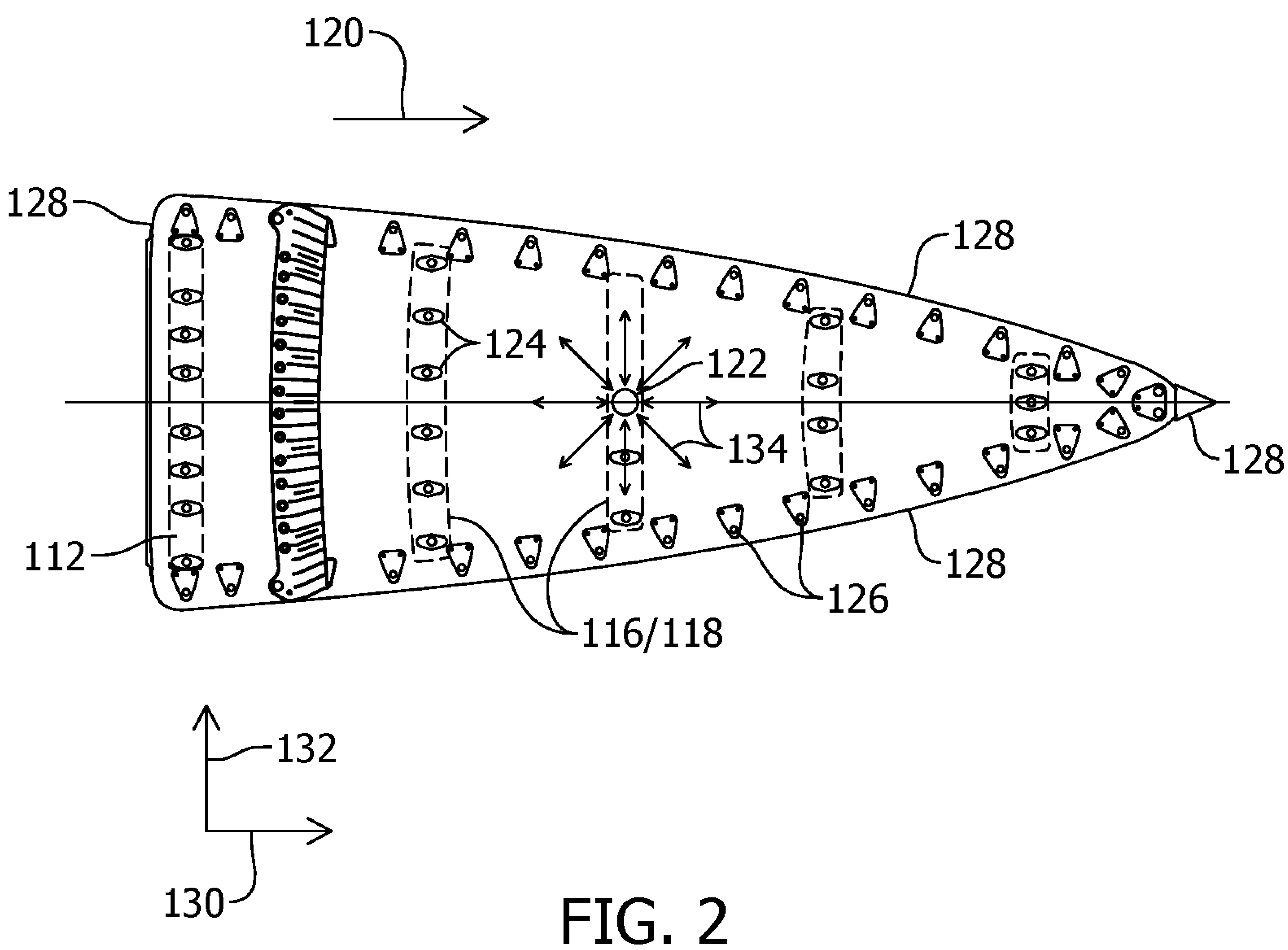
112
108
106

FIG. 1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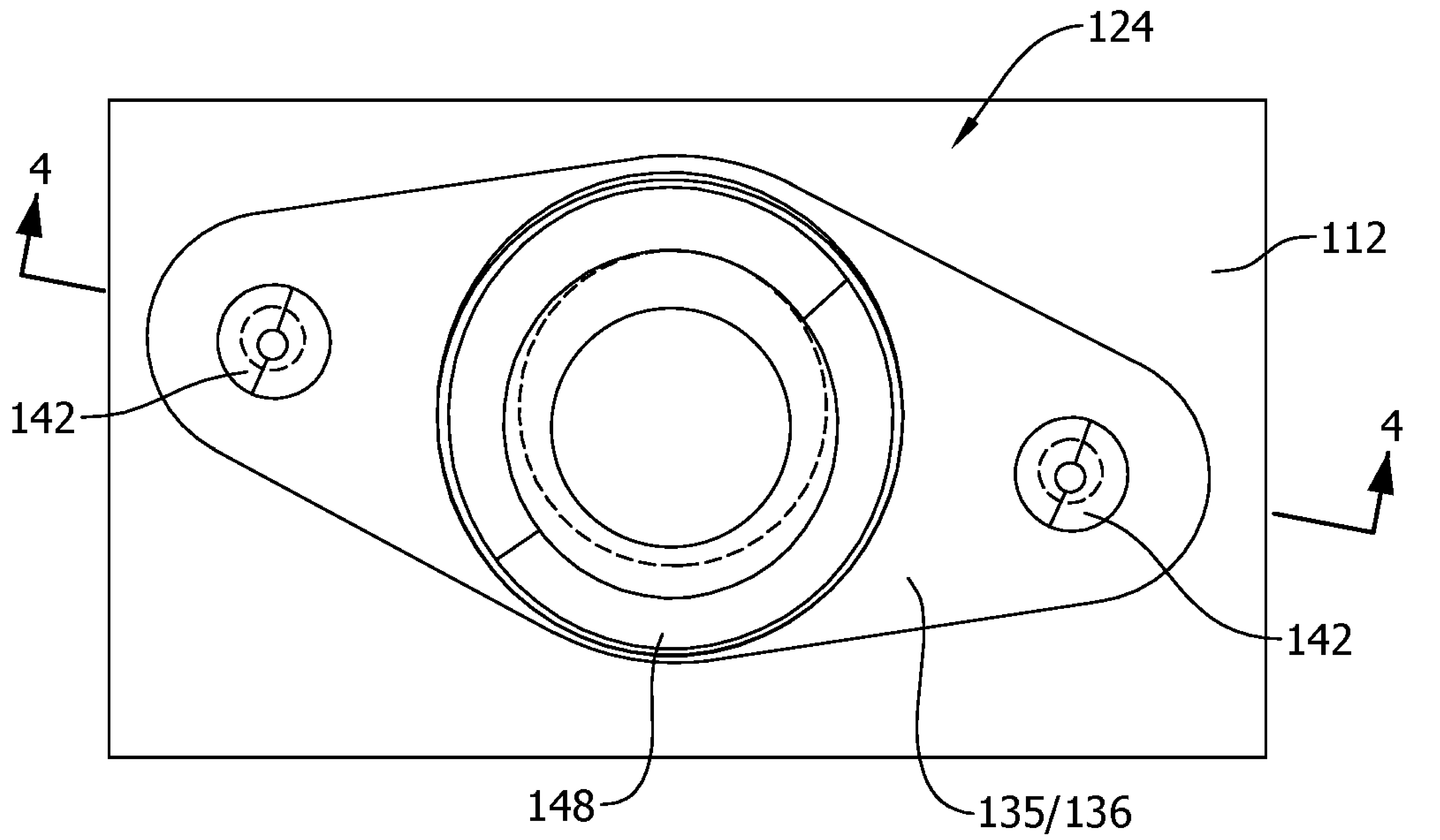
116/118
132
130

FIG. 2


124
4
112
142
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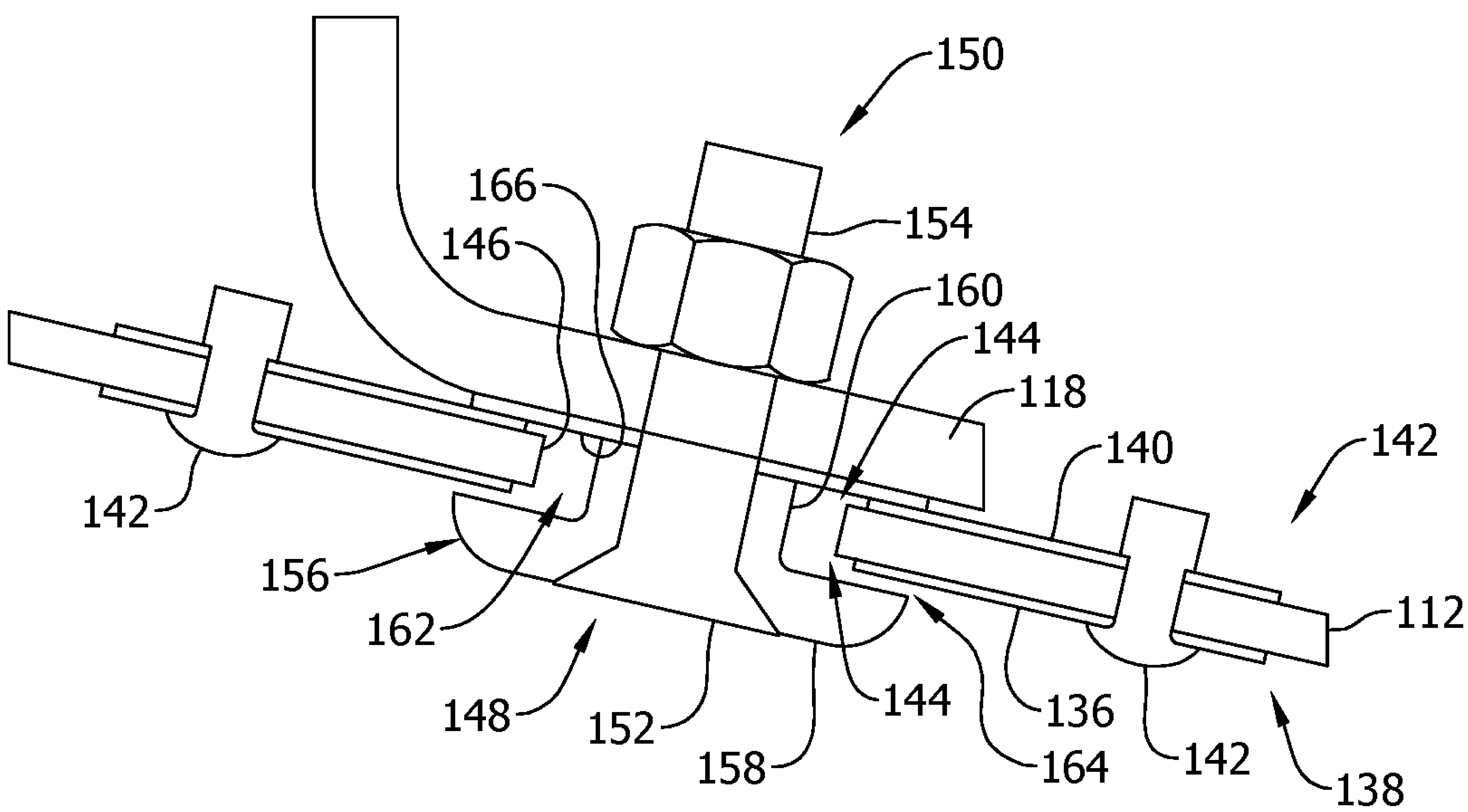
148
135/136

FIG. 3


150
166
154
146
160
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118
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156
162
112
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152
158
144
136
164
142
138

FIG. 4

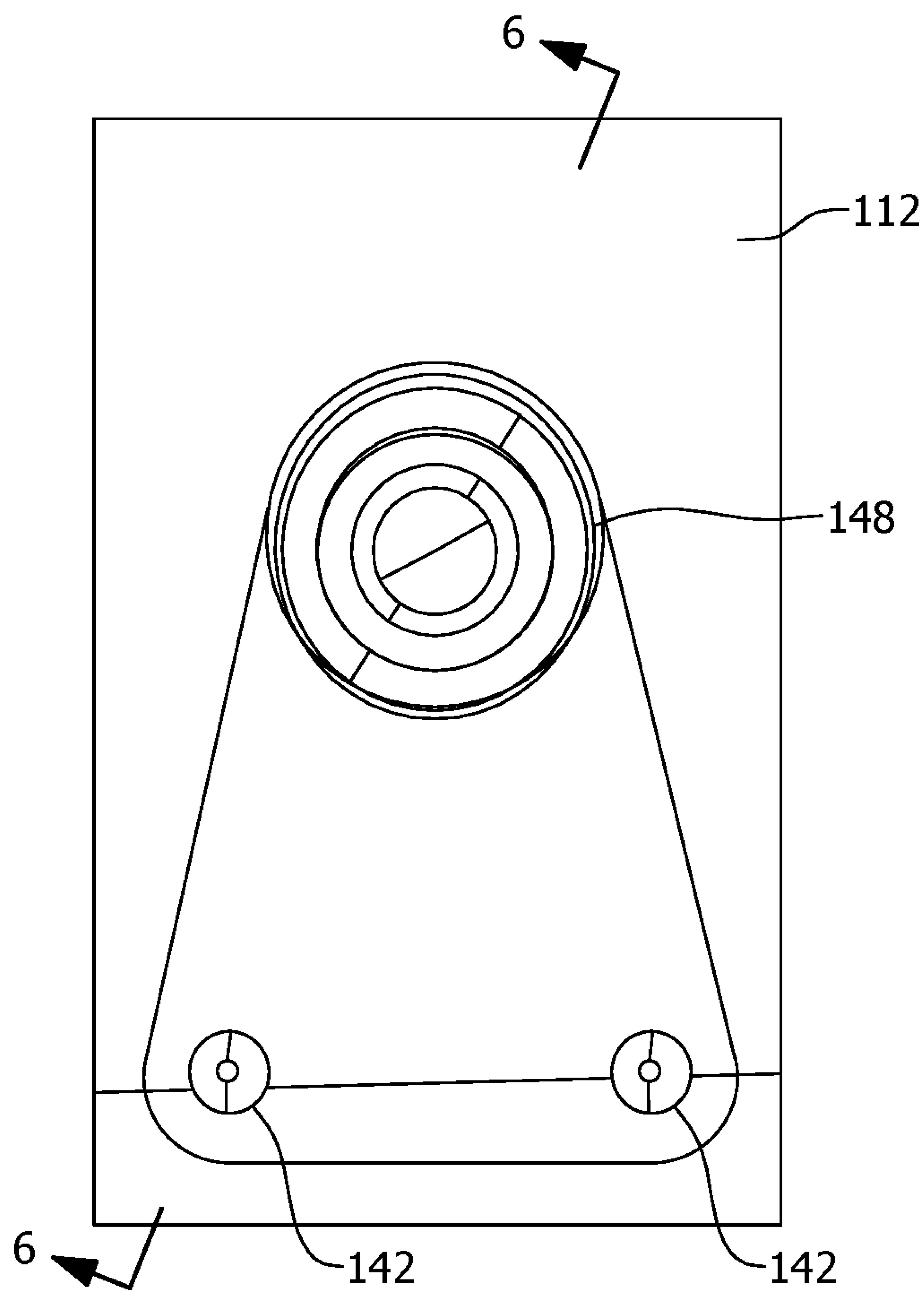
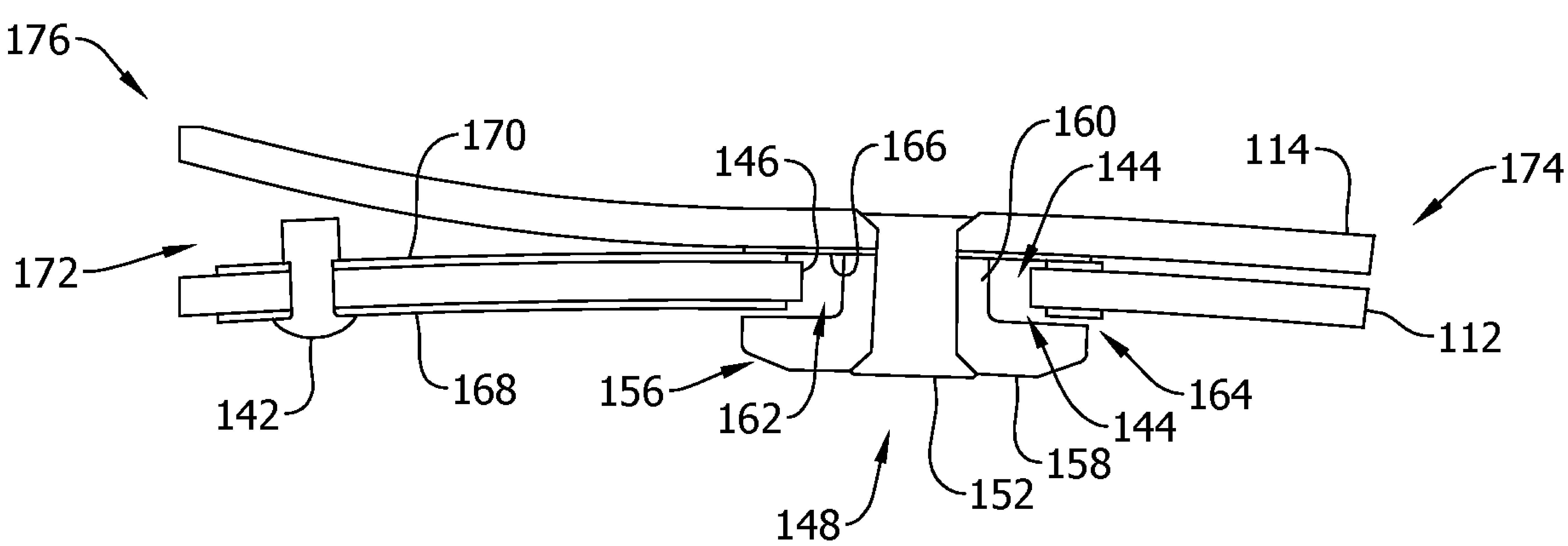

6
112
148
6
142
142

FIG. 5


176
170
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144
114
174
172
142
168
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162
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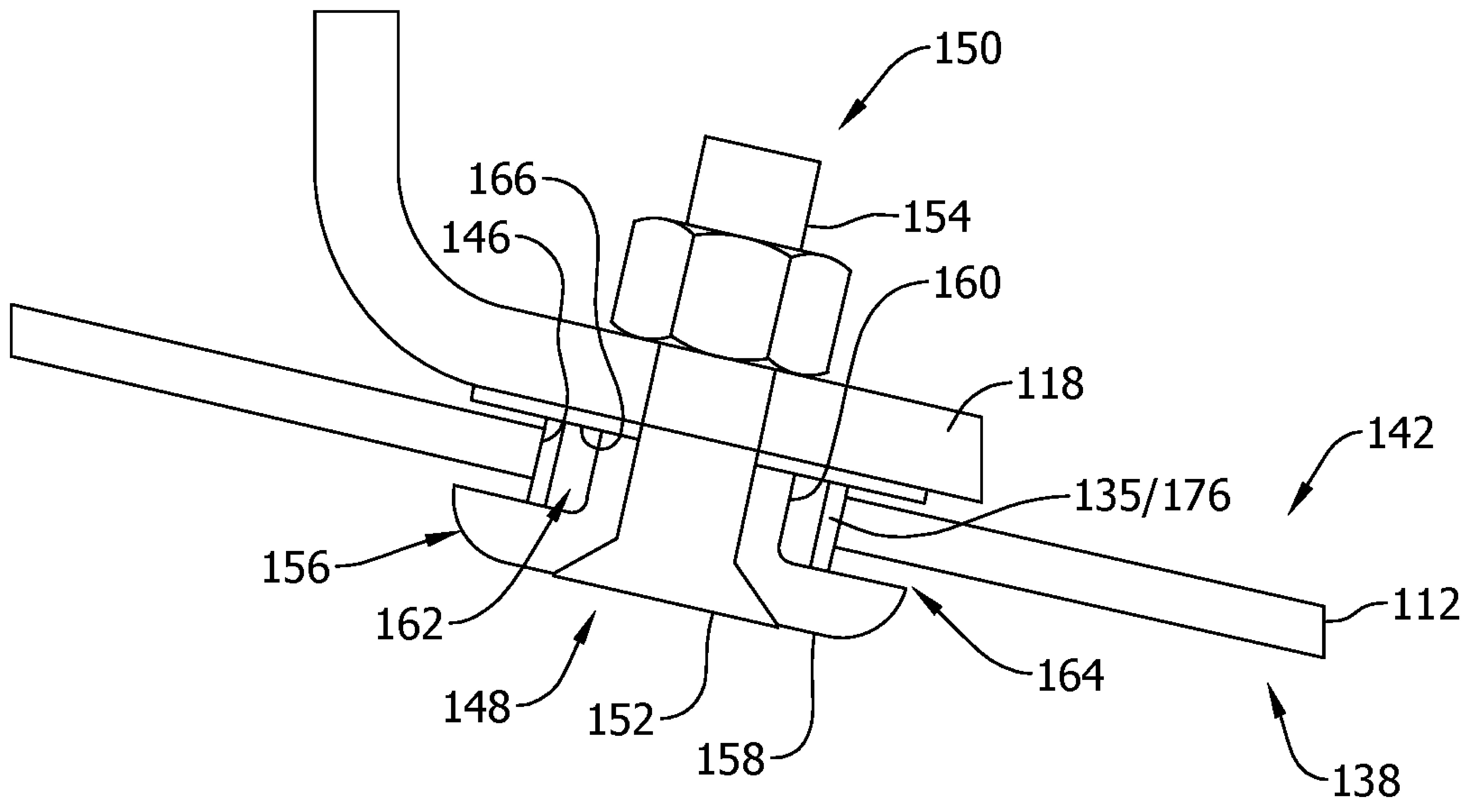
152
158
144
164
112

FIG. 6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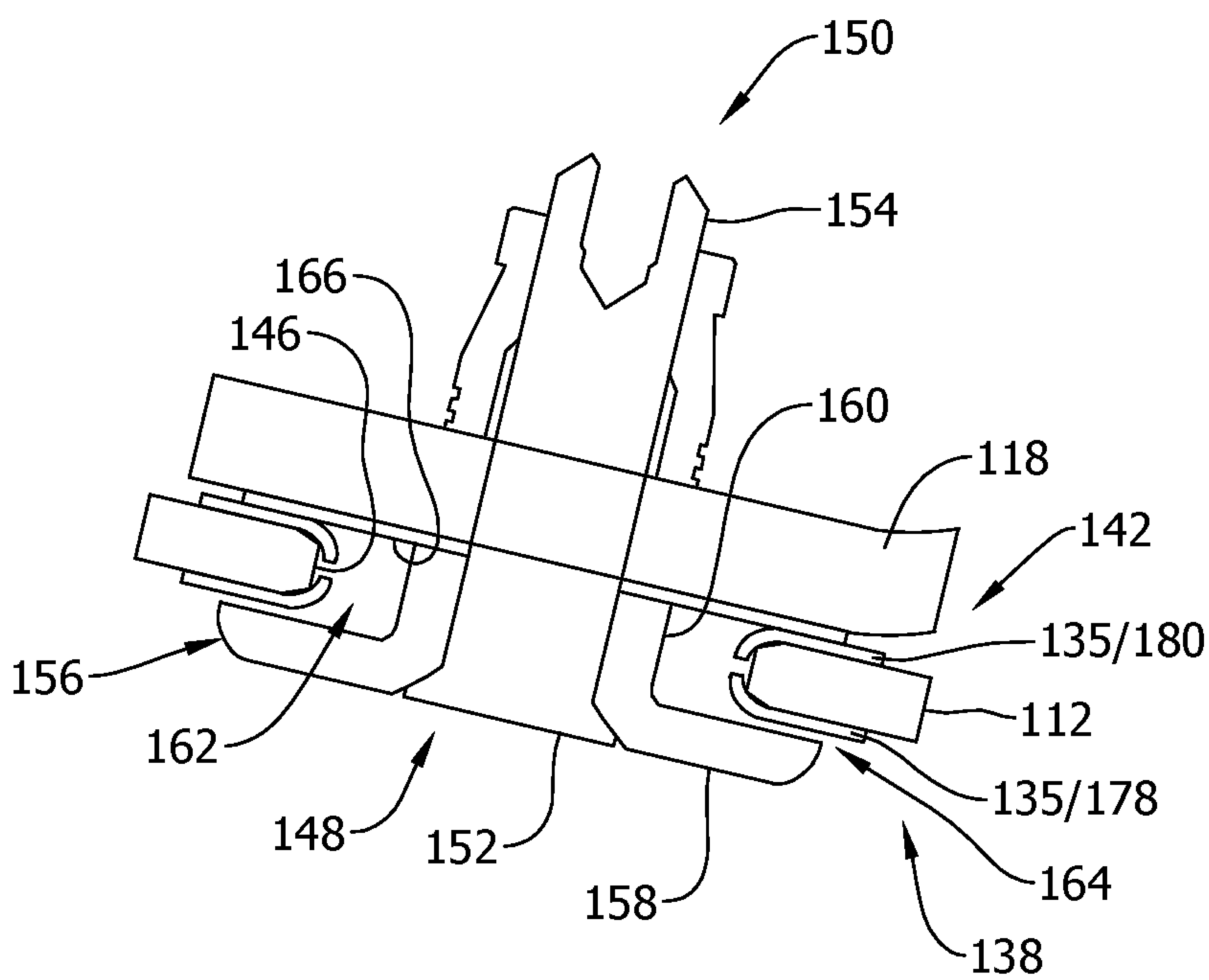
158
138

FIG. 7


150
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146
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118
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138

FIG. 8

# HEAT SHIELD ASSEMBLY FOR USE WITH AN AIRCRAFT ENGINE

## FIELD

The field relates generally to heat shields and, more specifically, to heat shields for aircraft engines that enable thermal expansion and contraction.

## BACKGROUND

Aircraft engines are typically supported on or coupled to an aircraft structure, such as a wing, with pylons. At least some known pylons include a support structure that supports the engine, and an aerodynamic fairing extending from the support structure. Some fairings are located aft of the engine such that a lower skin panel of the fairing may be exposed to exhaust gas discharged from the engine during operation thereof. Exposure to the exhaust gas use may cause the lower skin panel to undergo thermal expansion and contraction. Existing skin panels are generally continuously fastened to the support structure and to other skin panels with rivets. Temperature gradients may be formed across the fairing as the hotter lower skin panel is restrained by comparatively cooler side skin panels of the fairing. Thus, thermal cycling from exposure to the exhaust gas and subsequent cooling can repeatedly cause high stress to the fairing.

This section is intended to introduce the reader to various aspects of art that may be related to various aspects of the disclosure, which are described and/or claimed below. This discussion is believed to be helpful in providing the reader with background information to facilitate a better understanding of the various aspects of the present disclosure. Accordingly, it should be understood that these statements are to be read in this light, and not as admissions of prior art.

## BRIEF DESCRIPTION

One aspect is a heat shield assembly for use with an aircraft engine. The heat shield assembly includes a structural member, a heat shield panel adapted for exposure to aircraft engine exhaust, an index joint coupling the heat shield panel to the structural member in a fixed positional location, and a plurality of slip joints coupling the heat shield panel to the structural member. Each slip joint includes at least one wear buffer coupled to the heat shield panel, and a slip fastener insertable through a slip joint hole in the heat shield panel with a clearance fit. A gap defined by the clearance fit is sized to provide a tolerance for expansion and contraction of the heat shield panel relative to the fixed positional location, and the at least one wear buffer is engageable by the slip fastener during expansion and contraction of the heat shield panel.

Another aspect is a heat shield assembly for use with an aircraft engine. The heat shield assembly includes a structural member, a heat shield panel adapted for exposure to aircraft engine exhaust, and a plurality of slip joints coupling the heat shield panel to the structural member. Each slip joint includes at least one wear buffer coupled to the heat shield panel, and a slip fastener insertable through a slip joint hole in the heat shield panel with a clearance fit. A gap defined by the clearance fit is sized to provide a tolerance for thermal movement of the heat shield panel relative to the structural member, and the at least one wear buffer is engageable by the slip fastener during thermal movement of the heat shield panel.



Yet another aspect is an aircraft. The aircraft includes an engine configured to discharge exhaust, a heat shield panel positioned for exposure to aircraft engine exhaust, and a plurality of slip joints coupling the heat shield panel onto the aircraft. Each slip joint includes at least one wear buffer coupled to the heat shield panel, and a slip fastener insertable through a slip joint hole in the heat shield panel with a clearance fit. A gap defined by the clearance fit is sized to provide a tolerance for thermal movement of the heat shield panel relative to the slip fastener, and the at least one wear buffer is engageable by the slip fastener during thermal movement of the heat shield panel.

Various refinements exist of the features noted in relation to the above-mentioned aspects of the present disclosure. Further features may also be incorporated in the above-mentioned aspects of the present disclosure as well. These refinements and additional features may exist individually or in any combination. For instance, various features discussed below in relation to any of the illustrated embodiments of the present disclosure may be incorporated into any of the above-described aspects of the present disclosure, alone or in any combination.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a side view illustration of an example aircraft engine support structure.

FIG. **2** is a schematic illustration of a heat shield panel that may be used in the aircraft engine support structure shown in FIG. **1**.

FIG. **3** is an enlarged view of an example slip joint that may be used on the heat shield panel shown in FIG. **2**.

FIG. **4** is a cross-sectional view of the slip joint shown in FIG.

FIG. **5** is an enlarged view of another example slip joint that may be used on the heat shield panel shown in FIG. **2**.

FIG. **6** is a cross-sectional view of the slip joint shown in FIG.

FIG. **7** is a cross-sectional view of another example slip joint that may be used on the heat shield panel shown in FIG. **2**.

FIG. **8** is a cross-sectional view of another example slip joint that may be used on the heat shield panel shown in FIG. **2**.

Corresponding reference characters indicate corresponding parts throughout the drawings.

## DETAILED DESCRIPTION

FIG. **1** is a side view of an example aircraft engine support structure **100**. Support structure **100** includes a wing **102**, a pylon **104** extending from wing **102**, and an engine **106** is coupled to pylon **104**. In operation, engine **106** discharges primary exhaust **108** and fan exhaust **110** therefrom. Primary exhaust **108** is comparatively hotter than fan exhaust **110**. Pylon **104** includes a heat shield panel **112** and a side skin panel **114** extending from heat shield panel **112**. Heat shield panel **112** is positioned on an underside of pylon **104**, and is positioned aft of engine **106**. Accordingly, heat shield panel **112** is generally positioned for exposure to primary exhaust **108**, and side skin panel **114** is generally positioned for exposure to fan exhaust such that a thermal gradient is formed therebetween. In an alternative implementation, heat shield panel **112** is positioned in any location on an aircraft exposed to aircraft engine exhaust.

FIG. **2** is a schematic of heat shield panel **112**. Heat shield panel **112** is coupled to side skin panel **114**, and also to a substructure **116** of aircraft engine support structure **100**. Substructure **116** may include any component of aircraft engine support structure **100** that enables the heat shield assembly to function as described herein. In the illustrated example, substructure **116** includes one or more frame members **118** within pylon **104** (shown in FIG. **1**). Frame members **118** extend between wing **102** (shown in FIG. **1**) and heat shield panel **112**, are arranged in a spaced relationship relative to an exhaust flow direction **120**, and are oriented generally orthogonally relative to exhaust flow direction **120**. Substructure **116** may also include side skin panel **114** of pylon **104**.

Heat shield panel **112** may be coupled to substructure **116** with an index joint **122**, a plurality of first slip joints **124**, and a plurality of second slip joints **126** in a fastening pattern that enables heat shield panel **112** to thermally expand and contract to reduce stress. For example, index joint **122** couples heat shield panel **112** to a frame member **118** in a fixed positional location. Index joint **122** may include any suitable fastener that limits or eliminates movement of heat shield panel **112** relative to frame member **118**. In one embodiment, index joint **122** is generally centrally located on heat shield panel **112**. In other words, index joint **122** is spaced generally equidistant from opposing side edges **128** of heat shield panel **112** relative to at least a longitudinal axis **130** and a lateral axis **132** of heat shield panel **112**. Accordingly, thermal movement **134** of heat shield panel **112** is controlled relative to index joint **122**. More specifically, thermal movement **134** of heat shield panel **112** extends generally inward and outward relative to index joint **122**.

First slip joints **124** couple heat shield panel **112** to a respective frame member **118**, and second slip joints **126** couple heat shield panel **112** to side skin panel **114** inboard of side edges **128**. As will be described in more detail below, slip joints **124** and **126** provide a tolerance for heat shield panel **112** to expand and contract relative to the fixed positional location of index joint.

FIGS. **3** and **4** illustrate first slip joint **124**. First slip joint **124** includes at least one wear buffer **135** coupled to heat shield panel **112**. In the illustrated embodiment, the at least one wear buffer **135** includes a first wear pad **136** on a first side **138** of heat shield panel **112**, and a second wear pad **140** on a second side **142** of heat shield panel **112** between frame member **118** and heat shield panel **112**. Wear pads **136** and **140** are coupled to heat shield panel **112**, in a fixed position, with fasteners **142** such as rivets. The shape of wear pads **136** and **140** is determined by the locations of fasteners **142**. The locations of fasteners **142** are chosen so that fasteners **142** will not interfere or intersect with frame member **118**. Each wear pad **136** and **140** has an opening **144** defined therein, and heat shield panel **112** has a slip joint hole **146** defined therein at respective slip joint locations. Each opening **144** is aligned with slip joint hole **146** to enable a slip fastener **148** to be insertable therethrough.

Slip fastener **148** includes a bolt **150** having a head portion **152** and a body portion **154** extending therefrom. In the example embodiment, body portion **154** couples to frame member **118**, and head portion **152** has a wear spacer **156** coupled thereto. Wear spacer **156** has an engagement portion **158** and a sleeve portion **160** extending along body portion **154** of bolt **150**. Body portion **154** and/or sleeve portion **160** are undersized relative to slip joint hole **146** such that slip fastener **148** is insertable therein with a clearance fit. A clearance gap **162** defined by the clearance fit provides space for limited movement of slip fastener **148** therein, such as when heat shield panel **112** moves relative to slip fastener **148**. Accordingly, clearance gap **162** provides a tolerance for expansion and contraction of heat shield panel **112** relative to the fixed positional location. In addition, engagement portion **158** is sized larger than slip joint hole **146** and openings **144** in wear pads **136** and **140** to enable engagement portion **158** to extend across at least a portion of first wear pad **136**, as will be described in more detail below.

In addition, slip fastener **148** secures heat shield panel **112** to frame member **118** in a manner that enables the expansion and contraction to occur. For example, a nominal gap **164** may be defined between engagement portion **158** and first wear pad **136** such that a friction fit is defined therebetween. First slip joint **124** also includes a wear washer **166** between frame member **118** and second wear pad **140**. Accordingly, in operation, engagement portion **158** and wear washer **166** frictionally engage a respective wear pad **136** or **140** as heat shield panel **112** expands and contracts.

In the illustrated embodiment, slip fastener **148** is centrally located within slip joint hole **146**. Alternatively, slip joint hole **146** may be defined within heat shield panel **112** to positionally offset slip fastener **148** therein. For example, slip joint hole **146** may be offset at a "cold" position to account for the projected directional thermal movement **134** (i.e., expansion) as shown in FIG. **2**.

The wear components (e.g., wear buffers **135**, slip fastener **148** or one or more parts thereof, and wear washer **166**) of first slip joint **124** are fabricated from any material that enables the heat shield assembly to function as described herein. The wear material should be wear-resistant at high temperatures (e.g., greater than 1,000° F.). An example wear material includes, but is not limited to including, a nickel-based alloy material, a chrome carbide material, and a tungsten carbide material. Heat shield panel **112** may be fabricated from any suitable material, such as titanium.

FIGS. **5** and **6** illustrate second slip joint **126**. In the illustrated embodiment, first and second wear pads **168** and **170** of second slip joint **126** have any shape that facilitates reducing or eliminating interference between fasteners **142** and side skin panel **114**. For example, as shown in FIG. **6**, a panel gap **172** between heat shield panel **112** and side skin panel **114** on an outboard side **174** of heat shield panel **112** may not provide sufficient clearance for fasteners **142**. Accordingly, wear pads **168** and **170** are shaped and oriented to enable fasteners **142** to be positioned on an inboard side **176** of heat shield panel **112** where panel gap **172** is larger as compared to on outboard side **174**.

FIG. **7** is a cross-sectional view of another example slip joint that may be used on heat shield panel **112**. In the illustrated embodiment, the at least one wear buffer **135** includes a wear bushing **176** coupled to heat shield panel **112**. More specifically wear bushing **176** is undersized relative to slip joint hole **146**, and is positioned within slip joint hole **146** with a press fit. Thus, wear bushing **176** is in a fixed position within slip joint hole **146**, and provides sliding contact from a surface thereof that is frictionally engaged by slip fastener **148** as heat shield panel **112** moves relative to frame member **118** and slip fastener **148**. In some embodiments, at least a portion of wear bushing **176** protrudes from heat shield panel **112** to engage slip fastener **148** and/or wear washer **166** in the sliding contact.

FIG. **8** is a cross-sectional view of another example slip joint that may be used on heat shield panel **112**. In the illustrated embodiment, the at least one wear buffer **135** includes a first wear washer **178** on a first side **138** of heat shield panel **112**, and a second wear washer **180** on a second side **142** of heat shield panel **112** between frame member **118** and heat shield panel **112**. Wear washers **178** and **180** are coupled to heat shield panel **112** in a fixed position using any suitable fastening means. For example, wear washers **178** and **180** may be mechanically forced or swaged into position within slip joint hole **146**. Thus, at least a portion of each wear washer **178** and **180** are forced into slip joint hole **146** to affix wear washers **178** and **180** to heat shield panel **112**. Wear washers **178** and **180** therefore provide sliding contact from a surface thereof that is frictionally engaged by slip fastener **148** as heat shield panel **112** moves relative to frame member **118** and slip fastener **148**.

Accordingly, in the embodiments illustrated in FIGS. **7** and **8**, the various wear buffers **135** used are coupled to heat shield panel **112** without the use of additional fasteners, thereby reducing the weight of the assembly and reducing aerodynamic drag during flight operations.

Examples described include an engine fairing heat shield with the lower surface connected to an upper support structure with slip joints. The slip joints allow the hotter, lower surface to expand freely about a central location as it is exposed to engine exhaust flow. The slip joints are constructed of a nickel material to protect the surrounding structure from damage. In addition, the nickel material has excellent wear resistance even at high operational temperatures. The slip joint design is fitted with a clearance tolerance that allows the heat shield panel to move relative to the support structure while minimizing free play "chatter" behavior. Connecting the heat shield panel to the support structure at the fixed central location controls directional expansion and contraction of the heat shield, which enables a reduced tolerance to be provided at each slip joint. Accordingly, the examples described reduce high mechanical loads and stresses caused by exposure of the heat shield panel to the primary engine exhaust flow try.

As used herein, an element or step recited in the singular and preceded with the word "a" or "an" should be understood as not excluding plural elements or steps, unless such exclusion is explicitly recited. Furthermore, references to "example", "example implementation" or "one implementation" of the present disclosure are not intended to be interpreted as excluding the existence of additional implementations that also incorporate the recited features.

This written description uses examples to disclose various implementations, including the best mode, and also to enable any person skilled in the art to practice the various implementations, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the disclosure is defined by the claims, and may include other examples that occur to those skilled in the art after reading this specification. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal language of the claims.

What is claimed is:

**1**. A heat shield assembly for use with an aircraft engine, the heat shield assembly comprising:

a structural member;

a heat shield panel adapted for exposure to aircraft engine exhaust;

an index joint coupling the heat shield panel to the structural member in a fixed positional location; and

a plurality of slip joints coupling the heat shield panel to the structural member, each slip joint comprising:

at least one wear buffer coupled to the heat shield panel; and

a slip fastener insertable through a slip joint hole in the heat shield panel with a clearance fit, wherein a gap defined by the clearance fit is sized to provide a tolerance for expansion and contraction of the heat shield panel relative to the fixed positional location, and wherein the at least one wear buffer is engageable by the slip fastener during expansion and contraction of the heat shield panel.

**2**. The heat shield assembly in accordance with claim **1**, wherein the index joint is centrally located on the heat shield panel.

**3**. The heat shield assembly in accordance with claim **1**, wherein the at least one wear buffer comprises a wear bushing coupled within the slip joint hole.

**4**. The heat shield assembly in accordance with claim **3** further comprising a wear washer between the structural member and the wear bushing.

**5**. The heat shield assembly in accordance with claim **4**, wherein the slip fastener is coupled to the at least one wear buffer with a friction fit to enable the expansion and contraction of the heat shield panel.

**6**. The heat shield assembly in accordance with claim **1**, wherein the heat shield panel is formed from titanium.

**7**. A heat shield assembly for use with an aircraft engine, the heat shield assembly comprising:

a structural member;

a heat shield panel adapted for exposure to aircraft engine exhaust; and

a plurality of slip joints coupling the heat shield panel to the structural member, each slip joint comprising:

at least one wear buffer coupled to the heat shield panel; and

a slip fastener insertable through a slip joint hole in the heat shield panel with a clearance fit, wherein a gap defined by the clearance fit is sized to provide a tolerance for thermal movement of the heat shield panel relative to the structural member, and wherein the at least one wear buffer is engageable by the slip fastener during thermal movement of the heat shield panel.

**8**. The heat shield assembly in accordance with claim **7** further comprising an index joint coupling the heat shield panel to the structural member in a fixed positional location, wherein the thermal movement is defined by expansion and contraction of the heat shield panel relative to the fixed positional location.

**9**. The heat shield assembly in accordance with claim **8**, wherein the index joint is centrally located on the heat shield panel.

**10**. The heat shield assembly in accordance with claim **7**, wherein the at least one wear buffer comprises a wear bushing coupled within the slip joint hole.

**11**. The heat shield assembly in accordance with claim **10** further comprising a wear washer between the structural member and the wear bushing.

**12**. The heat shield assembly in accordance with claim **7**, wherein the slip fastener is coupled to the at least one wear buffer with a friction fit to enable the thermal movement of the heat shield panel.

**13**. The heat shield assembly in accordance with claim **7**, wherein the heat shield panel is formed from titanium.

**14**. An aircraft comprising:

an engine configured to discharge exhaust;

a heat shield panel positioned for exposure to aircraft engine exhaust; and

a plurality of slip joints coupling the heat shield panel onto the aircraft, wherein each slip joint comprises:

at least one wear buffer coupled to the heat shield panel; and

a slip fastener insertable through a slip joint hole in the heat shield panel with a clearance fit, wherein a gap defined by the clearance fit is sized to provide a tolerance for thermal movement of the heat shield panel relative to the slip fastener, and wherein the at least one wear buffer is engageable by the slip fastener during thermal movement of the heat shield panel.

**15**. The aircraft in accordance with claim **14** further comprising a wing and a pylon extending from the wing, wherein the heat shield panel defines a skin panel of an aft fairing section of the pylon.

**16**. The aircraft in accordance with claim **15** further comprising a structural member extending from the wing, wherein the structural member and the heat shield panel are coupled together with the slip fastener.

**17**. The aircraft in accordance with claim **16**, wherein the structural member is one of a frame member extending from the wing, or a side skin panel of the aft fairing section extending from the heat shield panel.

**18**. The aircraft in accordance with claim **14** further comprising an index joint coupling the heat shield panel onto the aircraft in a fixed positional location, wherein the thermal movement is defined by expansion and contraction of the heat shield panel relative to the fixed positional location.

**19**. The aircraft in accordance with claim **18**, wherein the index joint is centrally located on the heat shield panel.

**20**. The aircraft in accordance with claim **14**, wherein the slip fastener is coupled to the at least one wear buffer with a friction fit to enable the thermal movement of the heat shield panel.

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